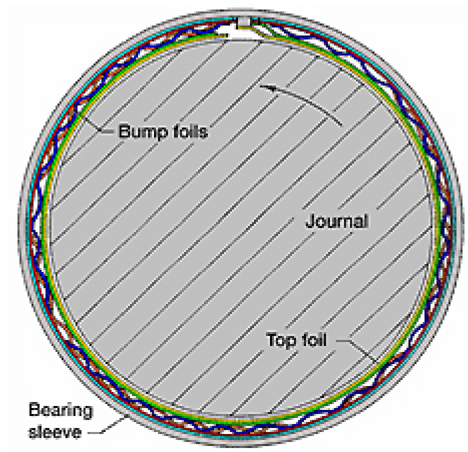
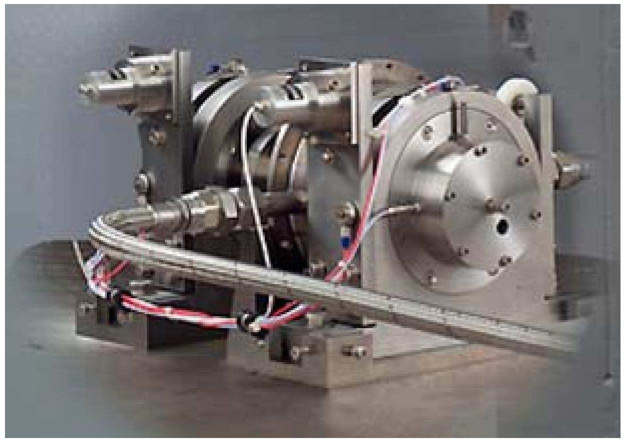
Research Capabilities for Oil-Free Turbomachinery Expanded by New Rotordynamic Simulator Facility



Foil bearing cross section.

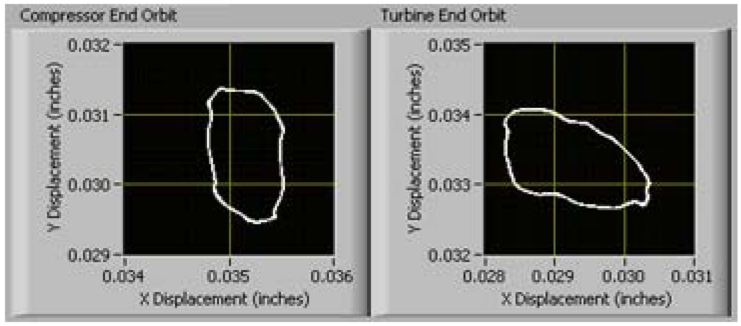
A new test rig has been developed for simulating high-speed turbomachinery shafting using Oil-Free foil air bearing technology. Foil air journal bearings are self-acting hydrodynamic bearings with a flexible inner sleeve surface using air as the lubricant (see the preceding illustration). These bearings have been used in turbomachinery, primarily air cycle machines, for the past four decades to eliminate the need for oil lubrication. More recently, interest has been growing in applying foil bearings to aircraft gas turbine engines. They offer potential improvements in efficiency and power density, decreased maintenance costs, and other secondary benefits. The goal of applying foil air bearings to aircraft gas turbine engines prompted the fabrication of this test rig. The facility enables bearing designers to test potential bearing designs with shafts that simulate the rotating components of a target engine without the high cost of building actual flight hardware. The data collected from this rig can be used to make changes to the shaft and bearings in subsequent design iterations. The rest of this article describes the new test rig and demonstrates some of its capabilities with an initial simulated shaft system.



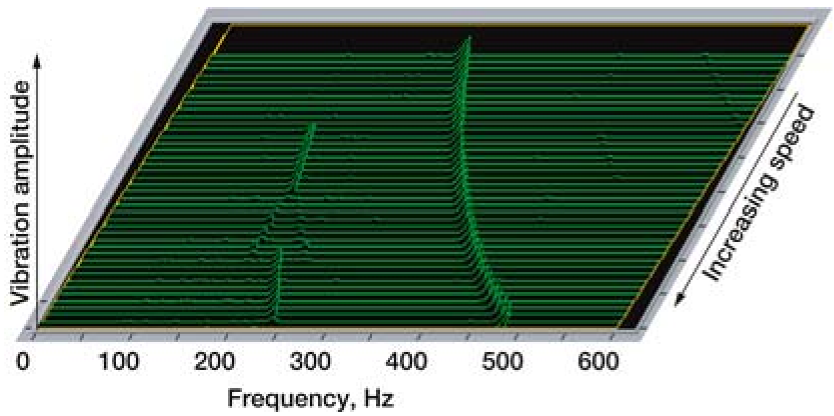
Rotordynamic simulator facility.

The test rig has two support structures, each housing a foil air journal bearing (see the preceding photograph). The structures are designed to accept any size foil journal bearing smaller than 63 mm (2.5 in.) in diameter. The bearing support structures are mounted to a 91- by 152-cm (3- by 5-ft) table and can be separated by as much as 122 cm (4 ft) and as little as 20 cm (8 in.) to accommodate a wide range of shaft sizes. In the initial configuration, a 9.5-cm (3.75-in.) impulse air turbine drives the test shaft. The impulse turbine, as well as virtually any number of "dummy" compressor and turbine disks, can be mounted on the shaft inboard or outboard of the bearings. This flexibility allows researchers to simulate various engine shaft configurations. The bearing support structures include a unique bearing mounting fixture that rotates to accommodate a laser-based alignment system. This can measure the misalignment of the bearing centers in each of 2 translational degrees of freedom and 2 rotational degrees of freedom. In the initial configuration, with roughly a 30.5-cm- (12-in.-) long shaft, two simulated aerocomponent disks, and two 50.8-cm (2-in.) foil journal bearings, the rig can operate at 65,000 rpm at room temperature.

The test facility can measure shaft displacements in both the vertical and horizontal directions at each bearing location. Horizontal and vertical structural vibrations are monitored using accelerometers mounted on the bearing support structures. This information is used to determine system rotordynamic response, including critical speeds, mode shapes, orbit size and shape, and potentially the onset of instabilities (see the following images). Bearing torque can be monitored as well to predict the power loss in the foil bearings. All of this information is fed back and forth between NASA and the foil bearing designers in an iterative fashion to converge on a final bearing and shaft design for a given engine application.



Sample shaft orbits at 15,000 rpm.



Waterfall plot showing synchronous and nonsynchronous vibration amplitudes.

In addition to its application development capabilities, the test rig offers several unique capabilities for basic bearing research. Using the laser alignment system mentioned earlier, the facility will be used to map foil air journal bearing performance. A known misalignment of increasing severity will be induced to determine the sensitivity of foil bearings to misalignment. Other future plans include oil-free integral starter generator testing and development, and dynamic load testing of foil journal bearings.

Find out more about this research at http://www.grc.nasa.gov/WWW/Oilfree/

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